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J. W. POWELL, DIRECTOR

PRELIMINARY REPORT

ON

SEA-COAST SWAMPS OF THE EASTERN UNITED STATES

BY

NATHANIEL SOUTHGATE SHALER

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SEA-COAST SWAMPS OF THE EASTERN UNITED STATES.

By N. S. Shaler.

GENERAL INTRODUCTION.

Among the most interesting results of the interaction of the sea and land are the swamps formed along the ocean shore. Such swamp deposits are found along most coasts. Although the special considerations of this report concern only the swamps of the New England and the more northerly portions of the American coast, it will be desirable to consider the outlines of the history of all sea-shore swamps, at least to the extent necessary to make the way clear to our study of the more limited field.

A very little study of the sea shore will show the intelligent observer that detrital matter is there subject to very peculiar conditions which are not found away from the narrow field where the sea comes into contact with the land. Over the whole surface of the land gravity, made free to act by the work of rain and frost, constantly urges detrital matter down the slopes of the continents towards the sea shore. Over the surface of the sea floor, except within the narrow belt from a little above high water to a few score feet below that level, this detritus is either stationary or is affected by very slight impulses. Within this shore belt, where the wave action is great, the movements of detrital matter are extremely varied, according to the ever changing movements of the sea, which vary with each tide, with each storm, and with every alteration of the geographical outlines of the vicinity. By these movements of the water the sedimentary matter is carried in varied directions, sometimes from the land to the sea; again, by a slight change in the equation of the forces, from the sea floor to the land. Here a cliff is undermined and its waste torn to pieces by the waves; there a narrow wall beach is thrown across an estuary; or dunes, composed of sea sand cast back upon the land and heaped up by the winds, may march across the lea, converting fertile fields to desert wastes or clogging the course of the streams on their way to the ocean.

The general tendency of these sea-shore forces is to cut away those projecting parts of the coast which rise above its surface and to heap

such part of the waste acquired thereby as may not be borne away from the shore line in the form of beach ridges, built along those parts of the shore which are so low as to present no cliff front to the waves. As the rivers in this part of the shore belt have the least fall, they are much hindered in their exit to the sea by these accumulations of débris.

Where there are great rivers bringing large quantities of sediment into the sea the swamp-building process is intensified, as in such positions the materials for the construction of beaches and the accumulation of morasses are more abundant; moreover, as is well known, the salt in the sea-water favors the precipitation of the mud, which is borne into it by the streams, and so the waves and currents have more waste at their command than in those parts of the coast where the silt comes from the beaches alone.

Whenever it happens that the shore line is undergoing a slow subsidence then the swamp-building conditions are made more favorable by the raised beaches which the sea is constantly building. This is conspicuously the case along the shores of the coast region from Chesapeake Bay to the Gulf, where the land is either subsiding or has been sinking in very recent times. These sea-built beaches, extending as long walls along the shore, hinder the outgoing of the land water, and thereby produce a vast extent of imperfectly drained country, which naturally has a swampy character. Even if a low shore is steadfast in its position in relation to the sea, the process of down-wearing of the land soon brings the surface into a condition of imperfect drainage. Any little elevation is lowered by erosion, and if the rocks be calcareous the leaching out of their soluble materials lowers them to near the sea level.

We should next notice the fact that the sea-board swamp deposits are divided into two distinct classes, viz, those which are formed with fresh water for their usual covering and those which are covered with salt or brackish water, to which the tides have free access. It is well known that there is a tolerably sharp demarkation between the organic life, both animal and vegetable, in the fresh water and that in the salt water. Moreover, the tidal action, as we shall see hereafter, brings a new element into the equation of forces involved in constructing the swamps to which it has access. The result is that the swamps covered by the land waters have the common type of terrestrial swamps, where the vegetable matter, with a chance admixture of river silt laid down during periods of flood, makes up the mass of the deposit; in the marine or salt-water swamps the salt-water grasses and sea-weeds commingle their waste with relatively large proportions of animal matter, and the ever-recurring tides supply a large share of detritus worn from the neighboring beaches. The result is deposits which have a large portion of inorganic silt in their composition.

The problem of swamp formation is further complicated by the fact that in southern countries, where the mean temperature remains high

for a long period and where the dryness of the air at certain seasons is considerable, the fresh-water swamps are subjected to a much more active decay than those in more northern climes, where the season of great heat is short and the air is more generally moist. The result is that in southern regions the accumulation of swampy matter can never raise the fresh-water morasses much above the level of the sea, or at least above the level of permanent moisture. Moreover, as we go southward the mosses belonging to the genus sphagnum, which are the most effective swamp-building plants now living, disappear, and their place is not taken by other species. The consequence is that the northern swamps, due to the blockading action of the sea, have a much better chance of extensive growth than those of the south. On the Atlantic coast of North America the southern limit of free-growing fresh-water swamps is found at Cape Hatteras, the system of the Dismal Swamp being the most southern extensive morasses approximating to the northern type. South of that line the fresh-water swamps are more and more affected by the climatal conditions as we approach the tropics.

Although the conditions of recent or still continuing subsidence favor the development of morasses in the southern regions, they do not have the vigor of development belonging to similar structures in the more northern district. On the other hand, we have the fact that the northern sea shore is in a state of elevation, or at least its movements have in geologically recent times been generally in the direction of elevation, so that the effect of the sea in barricading the shore has been small. Moreover, the shore is usually bold in its nature, and the interior has decided slopes toward the sea-board.

On the whole, the production of inland swamps due to the barriers built by the sea has been much greater in the northern portion of the continent than in the southern districts, though, as we shall see, the swamps formed in this manner are by no means wanting in the regions south of Cape Hatteras.

The swamps resulting from the coast actions may be generally classified in the following manner:

Salt water swamps—formed within the tidal influence by the combined action of salt-water plants, animals of various groups of invertebrates, together with detrital matter brought in by the tides;

Fresh-water swamps—formed when the lowlands have their drainage hindered by the barriers made by the rivers, composed of fresh-water plants, together with alluvial matter brought in by the fresh-water streams;

Estuarine swamps—formed where essentially fresh water is lifted and lowered by the tide, composed in the main of grasses and the alluvium of rivers. This group is very limited in its range. It may be illustrated by the case of the "vleys" or swampy borders of the Hudson River.

THE COAST SWAMPS OF NEW ENGLAND.

The development of the shore swamps of New England is intimately connected with the glacial history of this district during the last ice period. The forces at work in that period determined the shape of the surface and thus fixed the outline of the shore. The oscillations of level attending on the coming and going of the ice sheet did much to determine the history of the coast line. It will therefore be necessary to preface the account of the New England coast swamps with a brief statement concerning the effects of glacial action on its territory.

The rocks which underlie the surface over New England are of exceedingly diverse hardness: long-continued mountain-building actions, together with extensive local metamorphism, the intrusion of dikes, vein structure, &c., have brought these rocks to a state when the same degree of resistance to eroding agents is never found over any extended area.

The result of this irregular resistance to erosion was to give the surface, when being acted on by ice, an exceeding diversity of outline There are very few parts of this region between the Hudson-Champlain Valley and the Atlantic which have the bed rock horizontal over any area of even an acre of extent. I have rarely found a surface of this area with average inclination of less than five degrees of slope. The principal feature of the topography is the occurrence of long, deep troughs, with undulating floors, the axes of which lie in the direction of the old mountain synclinals.

It is a marked feature of this district (probably, indeed, of all regions which have their erosion outlines determined by glacial action) that the troughs or synclinals of the mountain folds are more eroded than the anticlinals. Observations on regions south of the glacial belt show that there the reverse is the case, the anticlinals receiving the most wearing and the synclinals the least; so that the latter axes become in time the highest parts of the country. As these anticlinals and synclinals of New England have in general northeast and southwest trends, or rather trends which run a little to the east and west of the meridian, the outline of the shore is in a great measure determined by their courses. As none of these troughs is smooth, but all are extremely irregular, owing to the erosion done by the ice, the contact of the sea with the shore has the peculiar aspect known as the fjord structure. This is not a peculiarity belonging alone to the shore line of glaciated countries, but is the shape which that line necessarily assumes where the level of the sea is laid against the land. If the New England coast were to be lowered by several hundred feet, as it was lowered at the close of the last glacial period, the shore line would be found to have the same fjord structure as at present.

An examination of the detailed maps of the United States Coast Survey giving the topography of the coast between New York and Eastern

Maine will show the reader that this fjord topography is expressed along the whole of this coast line. It is most distinctly shown in the section from Eastport to Portland, where the trend of the shore is such that the coast line cuts across the axes of the synclinals; it is less distinct in the section from Portland to Cape Cod, where the coast follows more nearly parallel to the direction of the mountain troughs, but it again becomes very clear in the section from Cape Cod to New York, where the trend of the coast is more nearly at right angles to the axes of the synclinals than on any other part of the coast south of Nova Scotia.

A glaciated district affords peculiarly favorable conditions for the development of both salt-water and fresh-water swamps. On the land the glacially formed contours afford abundant basins, which at the outset are lakes, but in time become converted into morasses. The formation of shore swamps is favored by the existence of abundant recesses or embayed portions of the shore, in which such accumulations can be protected from the assaults of the greater waves. The process of development of these salt-water marshes may be studied in almost any of the fjords of this shore. Their history is in general as follows, viz: At the close of the glacial period there was a time in which the coast was subjected to several sudden alterations of level. The rapidity of these movements is indicated by the general absence of old beach-marks within the belt occupied by the sea during the changes of level as well as by the condition of the kames and kindred glacial structures which have passed through the shore line in the process of rising and sinking of the land. Finally the land recovered from the extreme unsteadiness which the glacial conditions caused and assumed its present generally steadfast position. The rapid changes of level ceased at a time probably not more than ten thousand years ago, since which time the conditions now at work have been in operation.

The action of the waves on the shore is the first point that requires our attention. This action is greatest on the exposed headlands of the coast, for there alone do the waves have their greatest height. The materials composing these headlands are worn away and beaten into fragments, which are carried in the direction in which the waves are moving. The fragments formed by the beating of the waves are carried to the nearest beaches, which are always more or less inland, in reference to the eroding cliffs. On these beaches the pebbles are slowly ground into fine mud, which may be easily carried even by slight currents for considerable distances. A considerable part of this mud is taken out to sea by the undertow or bottom current which always sets from a storm-beaten beach along the bottom, but another part is urged by the movement of the water caused by the waves and of the tidal flow into the fjord, where it falls to the bottom. In this process of carriage the mud is generally conveyed along the shores and is most commonly deposited in the parts of the inlets near the shore

line. Wherever there is a bay within which the tidal current is deadened and where the waves have little play, this sediment is most rapidly laid down. If the process of deposition begins on a pebbly bottom, it is at first aided by the irregularities between the stones and the friction of the water among the sea-weeds, which frequently attach themselves to the stones. As soon as a sheet of mud is established, it commonly becomes occupied by a dense growth of eel-grass. This plant by its habit of growth greatly favors the deposition of sediment. The separate stems are set very close together, the interspaces not generally exceeding one or two inches. A tidal current of two miles an hour, swift enough to carry much sediment, is almost entirely deadened in this tangle of plants.

At half tide on the New England coast these eel-grass fields are generally covered with water to the depth of several feet; at this stage the tidal currents are commonly strongest. The water above the level of the grass has its usual freedom of motion and brings much sedimentary matter above the level of the foliage. As the tide falls a part of this waste is entangled and held until it gradually sinks to the bottom, so that each run of the tide gives a certain contribution of sedimentary matter, which goes to shallow the water. This process is easily observed from a boat floating over a field of these plants. The deadening of the current when the lowered tide brings the tops of the plants near the surface is very noticeable. The mass of floating matter — mud, fronds of sea-weed (often with shells or small pebbles attached to their bases), dead fish, and a mass of other refuse — is seen to collect in the mesh of foliage and sink to the bottom. The dead stems of the eel-grass and the bodies of many small crustaceans and mollusca which live on its stalks or on the bottom contribute to the deposit, so that it thickens with considerable rapidity.

When the bed formed on the sea bottom by the action of the eel-grass and its associated plants has risen to the point where it is dry at low water of the ordinary run of tides, the eel-grass can no longer maintain itself, but gives place to other groups of sea weeds and grasses.

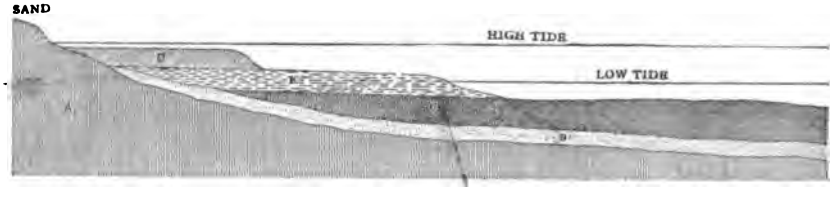


FIG. 51.— Diagrammatic section through a growing marine marsh.
A, bed rock. B, sand and gravel. C, eel-grass. D, upper marsh. E, mud-flat.

These species of plants find their place first near the shore line, where the eel-grass platform is naturally the highest. At first their vegetation is quite sparse, owing to the difficulty with which they endure the depth of water at high tide. There is often, indeed, a considerable dif-

ficulty in establishing the growth of the second group of plants, and for a while the deposit takes the shape of bare mud-flats, dependent in the main for their accumulation of detrital matter on the growth of certain mollusca, especially of the genera mytilus and modiola. It often happens that the scouring action of the tide restrains the upward growth for a long time; this is indicated by the very wide bench that lies between the level where the work of the eel-grass ceases and the higher plants establish themselves. Although this bench in most cases only extends through a vertical height of from three to four feet, the height depending on the measure of the tidal rise, it is often a mile or more wide. It constitutes the mud-flats of our shores.

When, as is usually the case, the more highly organized plants have difficulty in establishing themselves over the broad surface of the mud-flat, they win their way to it in the following manner, viz:

From the vantage ground of the shore line, where these plants easily find the conditions of submergence which suit their needs, the plants slowly extend the front of their bench out over the mud-flats (see Fig. 51).

This process of growth can be more easily studied than that of the earlier or eel-grass stage of the marshes, for it is visible along miles of our shore. The higher grasses have even more thick-set stems than those of the eel-grass flats; they entangle sediment even more effectively. At first their stems are covered for a few hours at each ordinary tide; they gather waste rapidly, and soon lift the plain which they are constructing up to the point where only at the highest tides are the tops covered by the water. At this stage the growth of the deposit is practically arrested, there being no means of increase save from the decay of the grasses themselves. At this period of growth the entrance of much sediment upon the area is strongly resisted by the tall grass upon the periphery of the marsh. The sediment is arrested upon this outer fringe of the plain, which is thus enabled to gain with considerable rapidity upon the mud-flat by the horizontal extension of the terrace, while, at the same time, it is constantly growing in height until it attains the maximum elevation of the deposit. This outer edge of the upper terraces of the morass is subjected to the constant friction of the tidal currents, as well as to the beating of the waves and the grinding of the ice in the winter season, so that in most cases its gain upon the area of the mud flat is slow.

The principal resistance to its extension comes from the action of the waves; by their blows a considerable amount of the face is worn away and the waste is distributed over the mud flat, thus adding to the thickness of that deposit and preparing it for the occupancy of the higher plants. In winter the ice chafes against this face with the rising and falling of the tide, often proving destructive to it. It is often seen to be undermined by these eroding agents; but in this case the superficial mat of closely interlaced roots holds together, and falling down over the escarpment acts as a revetment or curtain, securing it from further wear

and preparing the way for its speedy restoration by the rapid growth of the grasses in their new position. It is only when the waves have a sweep of a mile or more that they can effectively arrest the extension of the sheet; even then it is necessary that the tidal current be strong enough to bear the débris away from the mud flat before the victory of the waves is in any way lasting.

There is, however, a more definite limit to the encroachment of these upper-level salt marshes upon the tidal streams. As the marshes extend they narrow the channels occupied by the free-running tide until they reduce its flowage-ways to very limited bounds, the lines of which are determined by a delicate adjustment of the forces which extend the marsh area and the destructive scouring action of the tide exercised on its growing edge. There is no other case in nature, save in the coral reefs, where the adjustment of organic relations to physical conditions is seen in such a beautiful way as in the balance between the growing marshes and the tidal streams by which they are at once nourished and worn away.

The system of tidal circulation in a salt marsh is fairly well shown in small maps of the Green Harbor and Plum Island marshes, in which the main channels of this circulation alone are delineated. Besides these larger inlets of the tide there are many smaller channels which ramify through the marsh, by which the waters find their way over its surface, thus escaping, in a measure, the resistance which the close-set grasses would make to its direct passage over the swamp. So branched are these channels that there is hardly an acre of the natural swamp which is without one of their water-ways; its steep sides and tortuous course show its constant battle with the encroaching plants, which naturally grow with the most vigor near its banks. Owing to the fact that the greater part of our salt marshes have been partly subjected to the care of man, these narrow channels are often obliterated. The hay which the salt marshes produce, though scanty in quantity, has a certain value and is much esteemed by the New England farmers. These natural channels were much in the way of the harvesting of the hay crop, so nearly all these swamps have been ditched in such a way that the water now finds its entrance and egress by a system of artificial parallel channels a few rods apart. By this means the hay wagons and the mowers can find well arranged ways for their operations and the marsh is more quickly drained. Owing to these artificial channels, the natural streamlets have often disappeared, their beds rapidly growing up when the currents through them were directed into the artificial ways.

Even where this artificial modification of the swamps has changed the regimen of their lesser creeks, this water system remains one of the most beautiful exhibitions of natural forces which the sea shore affords. There being everywhere the same pressure of the growing sod against their streams, they are free to cast their curves into exactly the form

which the pendulum motion of their currents demands. At first sight it seems to the observer that the creek or salt-water stream is under much the same conditions as a fresh-water river traversing an alluvial plain; but a little observation will show him that the circumstances, though in a manner related, are in most ways extremely different. In the case of a true river its flow is constantly in one direction, and though the volume and energy of its current vary from time to time, it is only irregularly and at long intervals. In the salt-marsh river the flow is alternately in either direction, up or down stream, and this in a rhythmic manner twice each day, with brief intervals of perfect repose. The result is that the symmetry of the tidal-river curves far exceeds those of any fresh-water stream. In the river the effects of the frequently varied conditions can be traced in the curves, however symmetrical they may be; this gives them a certain irregularity. In the tidal river they may be perfectly balanced in their curvatures. In the fresh-water river the stream in the section where it is bordered by alluvial plains is usually burdened with a vast body of sediment, with which it is constantly struggling. It also brings a great deal of driftwood, which, lodging on the bottom or on the banks, perturbs the natural oscillations of the current and makes the outlines of the channel irregular. In the tidal river there is never any large amount of sediment; in no case enough to form bars; there is no driftwood; twice each day the perfect stillness of the water permits its burden to fall to the bottom. The only likeness in symmetry to these tidal rivers is found in the fresh-water swamps, whose clear natural streams flow through matter resembling in its process of growth the peat of the salt-water swamp, but even there the changes in the volume of the current make its curves less beautiful than those of the tidal marshes.

Although the foregoing account of the general history of the salt-water swamps of the Atlantic coast is true of these structures as a class there are certain differences in their character which depend upon circumstances peculiar to the various districts where they are formed. In regions where the soil is sandy, as, for instance, along the southern coast of Long Island, New York, the process of filling the shallows to the point where the grasses of the higher level may seize upon them is rapidly accomplished by the currents bringing in sand from the easily-worn headlands, so that the earlier or eel-grass stage of construction is omitted. In such regions extensive salt marshes may lie directly on a deposit of sand. Where the amount of drifting sand is very large it may entirely fill up the areas suitable for salt marshes before they have time to form.

The extent of the mud-flat stage of the developing terrace is also determined by the intensity of the tidal action, which in turn depends mainly on the height to which the tide rises. Where in the region near New York the tidal rise does not exceed about eight feet the currents are weak and their carrying power is relatively small. In the district

bordering on Long Island Sound the shore is not exposed to the open sea and the wave action is slight. These causes combine to make the sediment brought upon the flats of that region small in quantity and of very fine grain. The mud-flats are but little scoured and the tidal friction against the escarpment of the upper level of the marshes is slight. In this region the mud-flats, though often made, are not so deep nor so extensive in area as they are along the more northern shores.

Along the New England shore from Cape Cod to Portland, Me., the increased height of the tide and the greater freedom of movement of the sediment caused thereby, together with the greater action of the ocean waves on the unprotected shore, increase the rate of growth in the eel-grass level and add to the depth of the section occupied by the mud-flats.

Going as far east as the Bay of Fundy, where the tidal currents have several times the carrying energy which they have about New York and where the rocks exposed to the assault of the waves are of a softer nature than any other except the clays and sands of Tertiary or post-Tertiary age, we find a sudden increase in the proportion of sediment carried by the tidal currents. The greater part of this sediment is contributed by the Paleozoic and Mesozoic rocks of this section, principally by the red sandstones and shales of the Triassic period, which are exposed to the erosive action of the sea along extensive marine escarpments. The geological origin of this sediment is indicated by its prevailing red color, that being the hue of the greater part of the Triassic rocks of this district.

The quantity of this mud is very great; the currents which sweep it about are of remarkable strength, it being not uncommon to find tidal streams flowing with a current of six or eight miles an hour in the middle half of the tidal movement. The result is that wherever there is a deep bay in the recesses of which the tidal motion is slackened we find a very extensive deposit of mud. In this region, such is the energy of the currents and the amount of the sediment that both the eel-grass and the upper-grass portions of the detrital terrace are relatively limited, and the mud-flat portion is the striking feature in the coast topography. On the central parts of the New England shore, as about Boston, the mud-flat occupies at most two or three feet in the altitude above mean low tide and the annual addition to its mass in a year is very small. Thus in this latter district so slight are the currents which flow over the upper level of the marsh that the mud material which they deposit may not amount to as much as one-tenth of an inch a year. On the other hand, in the Basin of Minas, one of the principal inlets leading from the Bay of Fundy, the contribution of sediment is so great that vast areas have been easily reclaimed from the sea by building a rude inclosure around an area of the higher parts of the mud-flat, so that the speed of the sediment-laden waters is checked and they are made to lay down their burden. In a few years, often in a few months, this inclosed area is raised

to near the level of high tides. It is then only necessary to erect a barrier sufficient to exclude the tide, with exit gates for the rain-water, in order to have the land completely reclaimed from the sea. In this simple way there has been an area of many thousand acres of excellent arable land created along these shores.

The area occupied by the swamp deposits in different sections of the shore depends upon a variety of conditions. One of these, the presence of sheltered bays, has already been noticed. The original depth of water in the inlets is also a matter of great importance. These marshes are relatively rare along the coast of Maine, because the fjords of this section were originally very deep and the headlands are of such enduring rock that there is little waste formed by the waves which can go to shallow their bottoms to the point where the construction of the swamps can be begun. It will be some thousands of years before this portion of the shore has its waters shallowed to the depth where the marine swamps can begin to effect extensive reclamations from the sea. Although there are no very extensive salt-water swamps in the section between Portland and Eastport, they are frequently present as fringes along the shore, where the position is sheltered from the waves and the water is not too deep and the tides bring their usual supply of sediment. Along the Massachusetts shore the fjords were not originally as deep as those on the coast of Maine, and the very large amount of glacial drift on this part of the coast afforded material for the shallowing of the floors of the inlets to the point where the sea-weeds could begin their work of catching the sediment.

The presence of large amounts of pebbly material along a shore is also favorable to the formation of salt marshes by giving the waves an opportunity to construct barriers behind which the marshes may develop. These barrier beaches are particularly abundant along the Massachusetts shore, where the sea has abundant access to glacial pebbles and the coast is sufficiently open to the action of the waves to enable them to do their full measure of work. The best example of this action is seen in the Ispwich marshes, just south of the Merrimac River, and in the marshes about the mouth of the Saugus River, near Boston. The method in which these new inclosures are formed by the construction of barrier beaches is as follows:

When the coast shelf has been shallowed by the accumulation of sediment to the point where the space between the capes of a bay has been brought to within about 20 feet of the surface at the time of low tide, the conditions are favorable for the closure of the inlet by a barrier beach. In some time of heavy tempest, when the waves are running with energy into its open mouth, the seas mount too high to pass over the shallow without breaking. This breaking of the waves is caused by the excessive friction of the bottom of the wave on the floor of the sea, which so retards its on-going that the upper part of the wave shoots over the lower part and tumbles into confusion. It is precisely the

process so easily observed when the waves break on a shelving beach. As soon as the process of breaking begins, the forward motion of the wave is arrested, and the detritus which it was urging forward at once falls upon the bottom immediately in front of the arrested waves. In this way the barrier beach is begun. (Fig. 52.)

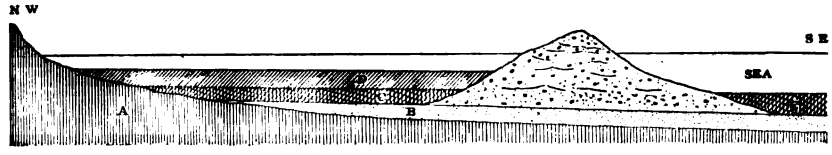


FIG. 52.—Diagrammatic section through Chelsea Beach and Saugus Marsh.
A, Bed-rock. B, Sand and gravel. C, Eel-grass layer. D, Upper marsh.

At first the beach may consist of a reef which does not rise above the water level, and probably is not complete across the whole of the space between the headlands of the bay; but generally the incoming mass of detritus carries the submerged ridge of the beach up to the level of high water, and the sea-wall is formed. Several excellent types of such barriers may be found on the northern shores of Massachusetts Bay in the beaches of Chelsea (or Revere), Lynn, and of Marblehead. If the beach stretches across the whole of the exit of the bay, there is an accumulation of land water behind the barrier which soon forces an exit. This exit may be permanent, as is the case with the exit from the marshes behind Chelsea Beach, and in most other cases where the inclosed area is large, or it may be subject to frequent closure, as is the case with the beaches on the south side of Martha's Vineyard, Cape Cod, and elsewhere, where the waves and tidal currents have a large amount of sand under their control. In these cases the outlet is constantly opening and closing.

If a tolerably constant connection with the sea be maintained, then the salt marshes, beginning with the eel-grass stage, rapidly win the ground from the sea. The front of the beach becomes a vast mill, upon which sediment is ground into the state of mud, to be swept into the area of the bay with the ingoing tide. The conditions given by such a barrier beach are the most favorable for the formation of salt marshes, as they include a large area of shallow water and an extensive sea beach, where a great amount of sediment, both organic and inorganic, may be produced. We consequently find that such areas are commonly completely occupied by salt marshes, except where lie the streams necessary for their natural irrigation.

If, however, the barrier between the lagoon and the sea is at times closed, so that the water in the lagoon becomes fresh, the result is that the plants which are especially adapted to the production of salt marshes are killed by the fresh waters, while the occasional invasion of the salt water destroys the fresh-water plants, which might otherwise establish a swamp of their species. By these alternations some of the largest

bays on the sandy shores have been kept from the invasion of the swamps, which would probably have been closed by them if the bays remained either fresh or salt water areas for a few thousand years. These inlets, where the growth of the salt marshes is liable to frequent interruption, are most common along the sandy shores of the coast, for the reason that in these regions the storms are able to shift large amounts of detritus in a short time, easily blocking the inlets to the lagoons, making the change to fresh water until some period of flood, when the land waters again establish a breach large enough to permit the tide to resume its work.

Although the regions where sand is abundant are, on the whole, unsuited to the normal growth of swamps, they are peculiarly favorable to the development of lagoons, which, except for the frequent alternations in the character of their water, are very well adapted to the growth of the swamp-making plants of the sea. An inspection of the Coast Survey charts will show the reader good specimens of these lagoons along the whole shore which is bordered by sandy material from Portland to New York. The commonest type of the lagoon is that which is formed by the breaking of the waves across the mouth of a bay, as before described. As these beaches are composed in the main of sand, they give little waste for the filling of the bay, for sand, as is well known, wears very little under the beating action of the waves. Another form of lagoon is produced by the extension of what are commonly called "hooks," which are in effect beaches that are extended beyond the shores on which they begin to form. When the projecting reef of the beach encounters a cross-current it is often so turned that it extends at an angle to its line of original growth, forming a great elbow, which embays an extensive area of water. Sometimes another beach forms across the open side of the bay thus created, completing the inclosure of the lagoon. The best specimen of this structure which our coast affords is that at the east end of Martha's Vineyard, known as Cape Poge (Fig. 53).

This promontory has the peculiar double beach, affording a complete inclosure within the sea built walls. Ordinary sand "hooks" of various sizes abound along the shores of Cape Cod and the region to the westward. Indeed, the eastern extremity of Cape Cod itself, including the northward-trending portion of its arm, is probably in large part of this nature. Except in cases where these inclosures are too much open to the sea, permitting the entrance of waves which are so strong that they break up the swamps, these lagoons are all the seats of such deposits.

There are certain general considerations connected with these salt-water swamps which deserve attention. First, we may note the fact that, although the New England shore affords unmistakable evidence of frequent alternations of elevation and subsidence within very recent times, no evidence of elevated marshes has ever been found. Although the upper coating of vegetable matter would doubtless soon decay and in

a short time lose all distinct likeness of its original shape, its character as a shelf abounding in organic remains and having a horizontal form should remain, provided these terraces were ever built at higher levels which are now above the plane of the sea. At many points along the shore, especially on the coast of Maine, and in other parts of New England, there are abundant deposits of clays known as Leda clay, which have been well preserved. These deposits were formed in deeper water than is required for the accumulation of salt marshes, and are hardly more likely to be preserved.

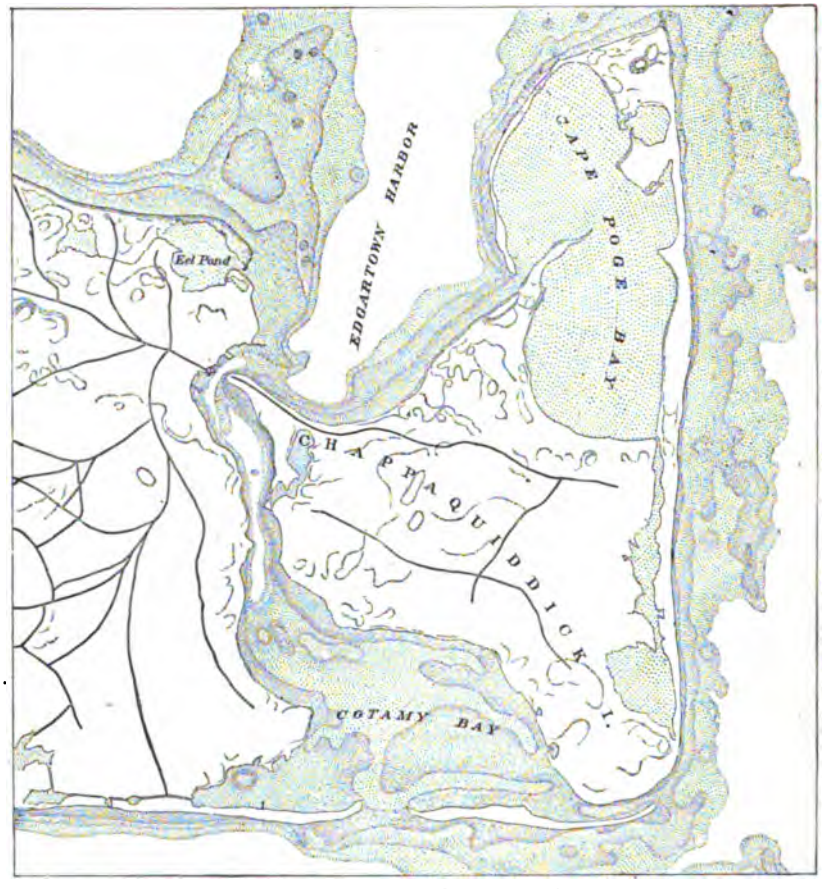


FIG. 53.— Hooks at eastern end of Martha's Vineyard.

This general absence of terraces which we might assume to have been marine marshes formed on the shores above the level of the sea at the close of the glacial period affords a fair presumption that th ese morasses have only begun to develop in an important way since the shore assumed its present level. This may be explained by the fact, abundantly shown by the absence of ancient erosive beaches and other evidence,

such as that from the kames, &c., that the duration of the subsidence at the close of the glacial period was very brief, and that the sea very quickly attained its present altitude, pausing at no time long enough to develop the characteristic features of a shore line.

Although there are no signs of old marine marshes above the present tide line, there is reason to believe that there are at some points considerable areas of salt marsh formation below the present level of the sea. On many of the New England beaches it is not uncommon to find large masses of the characteristic matted roots of the upper-level marsh-plants which have evidently been long buried beneath the sea. These fragments are particularly common along the north shore of Massachusetts Bay, though they are found at times along the whole coast from Portland to Long Island. Although it is possible that the detritus may represent masses of the present shore swamps, which have been carried away to deeper water by the action of ice and other transporting agents, and subsequently rejected by the sea, it appears to me most reasonable to look upon them as fragments of swamp deposits which have been buried by subsidence. This view is supported by many other facts, such as the occurrence of submerged forests, which go to prove recent subsidence of the coast line between Portland and New York.

Before passing from the general consideration of these salt marshes to take up the economic problems which they suggest, it will be worth the reader's while to consider certain general features of these singular structures. The remote and picturesque coral reefs have long proved fascinating subjects to the geological student, while these near-at-home structures, which are in their way almost as interesting as the work of the polyps, have never been adequately studied. In the northern part of Europe they have been the subject of much economic consideration, but there seems to be no scientific literature whatever on the subject. Yet these swamps are on many accounts the most remarkable features of the ocean shore line. They probably represent a larger share of solar energy applied through organic life to constructive geological work than is shown by the coral reefs; this is certainly the case if they play the same part along all the northern seashores that they have along the coast of New England. In the methods in which the work is done, in the beauty of the successions of growth, the exquisite symmetry of the system of irrigating canals in the completed swamp, they are not exceeded by the architecture of the coral reefs, admirable as those structures are.

The marine swamps may in their constructive work be well regarded as the complement of the destructive effect exercised by the celestial energy along the shore. The waves (the product of the solar heat) and the tides (the product of the gravitation impulse) bring about the destruction of the exposed portions of shore against which their movements act with destructive energy. A portion of the celestial force operating through organic forces constructs a system by which this wasting is in part compensated and the balance of land and sea pre-

served. Through its action the fjords are gradually closed and the indented coast is brought again to the form of straight shore lines.

The aggregate work performed by the plant and animal life in constructing the marine marshes and tidal mud-flats along the New England shore is very great. The total area of the true salt-marsh lands doubtless exceeds 200,000 acres. The average depth of the deposit, as determined by some score of observations, may be taken at 6 feet. Thus the total mass of the upper or true marsh amounts to about one-third of a cubic mile.

Besides the upper marshes, which in fact constitute only a small part of the work done by organic life on the New England shore, we have the mud-flat and eel-grass layers. These together form a deposit which has an area of at least 300,000 square miles and an average thickness of at least 12 feet. Observations on the thickness of this deposit are not sufficient to determine its thickness with accuracy. It may be found on the average to exceed 20 feet in thickness. Taking the least measurement which can be assigned as the thickness of the mud-flat and eel-grass layers, we have a total mass for the deposit amounting to nearly a cubic mile, which, with the deposit composing the upper marsh area, makes an aggregate of about 1⅓ cubic mile.

The above total does not include the materials gathered in these deposits which have been swept out to sea and deposited beyond the eel-grass layer. No basis exists for computing this matter, but it is evidently a large amount; it may much exceed that which remains in the deposits.

Although only a part of the matter contained in the above-mentioned beds is really of organic origin, the whole owes its position mainly to the work of organic life.

ECONOMIC PROBLEMS CONNECTED WITH MARINE SWAMPS.

A portion of the facts connected with marine swamps has a definite economic importance and will therefore be treated under this head. This matter is divisible into two branches: first, the effect of these swamps on the harbors of the coast line; and, secondly, the use of these swamps for agricultural purposes.

It is a well known fact that nearly all the harbors of all coast lines are subject to a gradual filling by the incoming sediments. When the winds blow toward the shore the waves urge the detritus which they carry farther in toward the recesses of the shore. When they blow from the shore the waves have so little transporting power that they do not return the detritus back into the sea.

The return of this detritus to the sea, if accomplished at all, is brought about by the action of the tide. The tidal action is more effective in transporting sediment from the harbor to the sea than in the reverse direction, because the slopes of the sea floor are to the seaward. The reader will readily perceive this fact by considering that if equal amounts

of force are applied to rolling a ball alternately up and down a slope twice a day for many thousand years, although the slope be of very slight declivity, say less than one degree of inclination, it is evident that there will be a constant tendency of the ball to work in the direction in which the surface slopes. This is essentially the condition of the sediments in our harbors; they lie on surfaces which slope to the sea ward and the tide meets with a little more resistance in urging them up these slopes than in dragging them downwards. There is an additional though variable tendency to a seaward movement of the sediment, due to the efflux of the land waters. This is particularly evident in the case of narrow fjords like that of the Hudson, through which a large stream discharges its waters into the sea, but in most cases the influence of the land waters in the scouring of the harbor is small. In Boston Harbor, for instance, the rivers, though of some size, have little scouring effect except in their own channels.

Thus we see that the amount of tidal flow which passes through the water-ways of a harbor is a matter of great economic importance; anything which serves in any way to diminish the volume of the tidal flow may give the persistent waves a chance to close the harbor with the sediments they are constantly urging into it. This importance of the tidal flow in the regimen of our harbors has long been recognized. The commissioners in charge of the most important ports take great pains to guard their tidal basins from infringements which may lessen the volume of water which passes through the important channels; they do not allow any of the areas flowed by the tide to be filled unless an equal water-storage area is provided by excavations. It has been found by experience that the extensive filling of tidal flats in the days before the harbors were properly controlled by law had a decided tendency to shallow the water in the ways by which the tidal wave passed to and from the sea.

These experiments, as well as the theory of tidal action, make it plain that the extensive accumulations of the salt-water marshes must exercise a great influence on the scouring action of the tides, and that this tendency must generally be to diminish the energy of their work.

There can be no question that the restriction in the tidal area due to the formation of the marine swamps has greatly contributed to the filling up of the harbors in which they have been formed. In the system of inlets about Boston Harbor nearly one-half the total original area has become occupied by these swamps. The average original depth of the water on this marsh-covered area at high tide was probably not less than 20 feet. At the present time the depth of water at high tide will not average much over a foot.

Thus there is about one-half less tidal flow through the inlets of the harbor than existed when the shores attained their present position. As will be seen from the list of the tidal marine swamps given in the last part of this memoir, or as can be better judged from an inspection

of the admirable Coast Survey chart of the New England shore, these swamps are most apt to form in the more interior parts of the fjords, where they are in a position to do the most in diminishing the flow of the tide. Unless the rapid growth of these marshes is restrained by artifi cial means they will in time diminish the depth of the water in all the harbors where they are extensively developed.

The rate of growth of these marine marshes is not determined. At the few points where I have been able to get any observations upon it the conditions had been so perturbed by recent artificial changes in the run of the currents that these observations have no value in reference to the normal advance of the shelf on the shallow water. It is evident, however, that the growth is on the average extremely rapid, for the reason that at many points the front of the sheet of the upper terrace has gone forward from 5,000 to 10,000 feet since the growth began. At present, however, the growth is evidently much slower than in the past, for the reason that the shallow-water areas have been generally covered by the marsh growth, and the further advance is resisted, not only by the depth of the remaining areas, but by the friction of the tide against the border of the upper terrace.

In a certain way the growth of these swamps may be regarded as preservative of the harbors. The inorganic matter which is employed in their construction is that which is brought into the harbors by the tidal currents or washed from the neighboring shores; this material alone would accomplish a great shoaling of the water. The growth of the upper marsh shelf against the tidal current, as before described, causes the main tidal ways which traverse the marshes to retain at least their original depth and in some cases to scour out much deeper channels than they at one time occupied. In this way the navigable inlets of the Charles, the Mystic, the Saugus, and other rivers have been formed and maintained, where if there had been no constriction of their ways these inlets would at low water have had no definite channels.

Thus it may be said that while the salt marshes tend on the whole to destroy harbors they also tend to develop and preserve certain narrow channels through which the water which nourishes and extends the morasses finds its path. In a word, their tendency is to convert broad harbors into narrow channels.

We now come to the second economic consideration, viz, to the problem of gaining these marshes to the use of man. This question can only be set forth in a very general way, for the complete discussion of the matter would require an extended treatise. It should at the outset be noticed that the utilization of these deposits for agriculture is by no means a new problem; essentially similar areas in Northern Europe have been extensively reclaimed. A large part of the agricultural grounds of Holland and extensive areas in other northern parts of Europe were originally in the condition of the salt marshes and mud-flats of our Atlantic coast. As has been already indicated, extensive areas of these

deposits have already been won from the sea along the shores of the Bay of Fundy. Not less than 60,000 acres of such reclamations have been made during the last century in that part of the American coast. Some experiments have been made in winning these grounds to agriculture along the New England coast, but in most cases they have been limited to the simple task of bettering the natural drainage, so that the marsh hay which they produce could be more easily harvested. Where efforts have been made to exclude the sea and actually till the land they have sometimes been unsuccessful, owing to the failure of those who carried on the trial to see the true conditions of the work. It is very much to be regretted that these experiments were not directed by some one trained in the work as it is effected on the northern shores of Europe, who could have brought to the task the accumulated experience of centuries; if this had been done it is tolerably certain that the process of turning these American marshes to agriculture would now be well advanced.

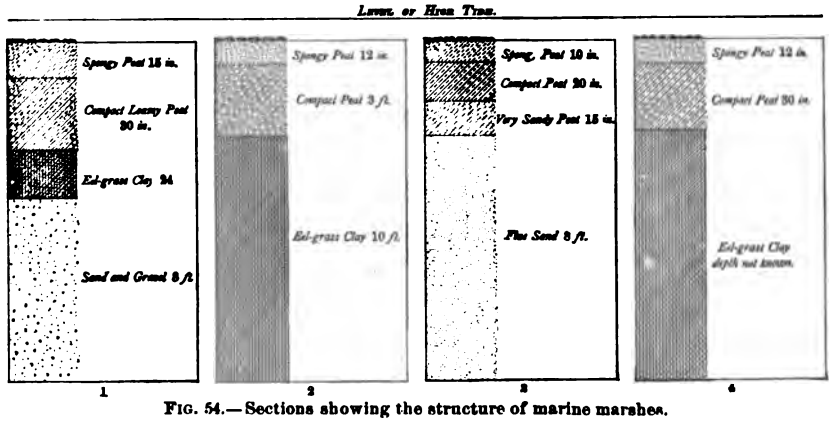


FIG. 54.—Sections showing the structure of marine marshes.

1. Saugus marshes. 2. Charles River marsh. 3. Plum Island marsh, north end. 4. Plum Island marsh, south end.

In considering the fitness of this extensive area for the uses of agriculture we should first notice, once again, the fact that the deposits generally consist of three distinct levels (see Fig. 54): first, the eel-grass level, which is too deeply buried in the water to make its winning to dry ground possible in the present state of our agriculture. Next higher come the mud-flats; a part of this deposit is generally within limits of height which make its redemption possible. A very large amount of these mud-flats lies within six feet of the high-tide level. In the area from Portland to New York probably more than one-half of the mud-flats lie within that limit of height. It is only when this mud-flat level has grown to within about 5 feet of the high-tide mark that the upper terrace succeeds in covering it.

Thus a general section through the whole marine marsh—including that formed in the eel-grass, that formed when the deposit was made

on the mud-flat, and finally the last formed and highest salt marsh proper—is made up of three sections, which have a decided diversity in their character: the lowest deposit is generally of a clayey nature, though it is often mingled with sand or pebbles and marine shells; the section formed on the mud-flat is composed of clayey materials, but it generally contains more vegetable and animal matter than the lowest-lying mass. The latter deposit is mainly composed of the part of the upper terrace which is broken up by the waves. This middle or mud-flat part of the section has every element necessary to form a very fertile soil as soon as the salt with which it is charged is decomposed. The upper layer, or shelf, of the salt marsh contains a good deal of clay and much animal organic waste, but its principal component is vegetable matter. This carbonaceous matter varies in a diminishing ratio from the surface downward. Six inches from the surface the average of several analyses taken from different points near Boston, Mass., gives about 50 per cent. of carbonaceous matter, while at three feet from the surface the amount probably does not exceed 20 per cent. This part of the marine marshes evidently contains far too much vegetable matter, at least in its superficial layer, to make a satisfactory soil. The proportion of common salt is also excessive.

If the process of winning these lands from the sea is to attain a full measure of success, it must take account of these features. Steps must be taken to get rid of the superfluous vegetable matter by permitting it to rot and time must be given and the conditions made favorable for the decomposition of the salt or for its washing away by the water. In all the experiments hitherto tried on the New England shore, the farmers seem to have expected that immediately on the fencing out of the sea that the land would be fit for the plow and for the planting of any crop. In practice they have sometimes found that the first result was to destroy the value of the marsh for its natural crop of salt grasses, while, for some time, it was unfit for the growth of the land grasses or, in fact, for any other valuable crop except oats. Deep plowing, underdrainage, and the necessary patience with the process of changing the conditions of the soil have usually been wanting in these experiments.

In an effort to win these soils to the plow the farmer would do well at the outset to select those parts of the area where the upper terrace deposit is the thinnest, not, as has always been done, choosing those places where the level of the marsh was the nearest to the high tide line. A general determination of the depth of the less tillable upper terrace can easily be made by means of simple observations on the altitude of the mud-flat which lies outside of the upper marsh. The upper element may be assumed to extend downwards to the level occupied by the top of the mud-flat. This may be verified by the proper borings, which may be made with the implement known as a post-hole auger or by any other means. The proportion of vegetable matter may easily

be determined with sufficient accuracy by burning a pound of the material, weighed after it has been dried in an ordinary oven, then heating the same to redness in an iron vessel upon a fire, and afterwards reweighing the mass. If the amount of vegetable matter does not exceed one-half the total weight for the upper two feet of the section, as will be the case if the weight of the mass does not diminish by more than 50 per cent. under this treatment, then the upper swamp can easily be brought into a condition for cultivation. If the proportion of vegetable matter much exceeds this amount, the difficulties of bringing the surface into a good shape for tillage will be increased.

The first aim of the cultivator should be to make sure of the exclusion of the sea. This can generally be effected in the following manner:

Where the lands are not open to the broad water, a simple closely-set row of stakes or piles should be driven two feet or more into the earth. These stakes should rise at least two feet above high-tide mark, and more if the waves from the open water make additional height necessary, and they should be sheathed by planking on the inner side. Behind them there should be a stout rampart of sods and earth, the sods being placed against the close-set stakes and on the inner side of the barrier. This rampart, if its height be 6 feet, should have a base at least as great as its height. It may advantageously be secured on the inner side by means of planking or a row of stakes for a portion of its height. Such a simple dike will serve for most small areas when the barrier is not much exposed to the action of the waves.

Well-constructed automatic sluices should be provided for the escape of the land waters, so arranged that the ordinary level of this water should not come within three feet of the level of the soil, and, if possible, as much as five feet of clear elevation above the standing water should be attained. Sufficient catch pools should be provided for the reception of the land water during the time when the tide is too high to permit its discharge. This can usually be contrived, without the expense of excavation, by inclosing a portion of the open channels that traverse the marsh or parts of the low-lying mud-flats always bordering the swamp on the sea side. If the expense of this work is to be considerable it will in all cases be desirable to have the dike planned by a competent engineer. These suggestions are meant rather for the guidance of those who desire to make small experiments than for those who intend to undertake large enterprises of this nature.

Having secured the area from the invasion of the sea, the next care of the cultivator should be to bring about the most rapid decay of the vegetable matter contained in the uppermost part of the marsh and the decomposition of the salt which it contains. This will, in the course of years, be accomplished by the natural process of decay; but the process proceeds slowly unless it is hastened by artificial means. The spongy character of the marsh causes it to hold moisture in a firm way, and as

long as it is moist its decay is retarded. Deep plowing is therefore an indispensable requisite in the process of betterment.

After a year of exposure the upturned ground will commonly be fit for crops of oats, but it will be at least three years before the surface will be found in condition for general tillage.

Those who undertake the improvement of our swamp lands will do well to limit their work at first to a small area, not exceeding a few acres, so chosen as fairly to represent the general conditions of the reclaimable areas and to avoid the difficulties which come from the invasion of the land waters in times of flood. Wherever there are large areas of marshes there is a great field for selection in this regard. The experience gained on these limited fields may then be extended to larger areas.

The principal difficulty which will have to be encountered in utilizing our American marshes for agriculture will arise from the excessive rain at certain seasons. Where the tide has a fall of less than six feet this difficulty can generally be met by the use of storage basins with sufficient exit ways to be automatically opened in the low state of the tide. On the more southern shores of the United States — all those in the region south of the Delaware Bay — it is likely that any effective work of drainage will have to be connected with a more costly method of removing the water by means of windmills operating pumps, as is now done in Holland and elsewhere in Europe. This is perhaps not practicable in the present condition of American agriculture, and may not be so until the increase of population puts a higher value on tillable ground. Still these southern salt marshes and mud-flats constitute a most valuable reserve of lands which will hereafter be won to man's uses.

The great advantage of the more northern marsh areas is found in the fact that they are generally near the larger centers of population of the country, where they will have a high value as market-garden soils or fields for the raising of hay. When brought into their best state such areas will, measured by the price set upon other lands in the same neighborhood, have a value of not less than $200 an acre. As the total reclaimable area between New York and Portland probably exceeds 200,000 acres, the money value in their best state will amount to at least $40,000,000. The cost of reclaiming these areas and reducing them to cultivation should not exceed the fifth of this sum.

It may be noted that from the chemical composition of these soils they are practically inexhaustible and that from their position they are often well placed for irrigation.

South of the New England shore the marsh area is much more extensive than in that region. It is probable that the improvable marshes of the Atlantic coast amount to at least 3,000,000 acres and they may exceed double this amount. As yet too little is known of their conditions to make it worth while to discuss their prospective value, but it is evident that they are well worth a serious inquiry.

DETAILED ACCOUNT OF SELECTED AREAS OF SALT-MARSH LANDS.

It has not seemed desirable to give a detailed description of the marine marshes which are noted in the following catalogue. The descriptions given below concern only two of the most important areas. That describing the Plum Island marsh is given because the marsh in question is the largest connected area of such land on the New England shore as well as one of those most favorably placed for improvement. The account of the Green Harbor rivers is warranted by the fact that it has been the seat of the most important experiment in winning these marshes to agriculture which has been essayed on any part of the shore north of New York City.

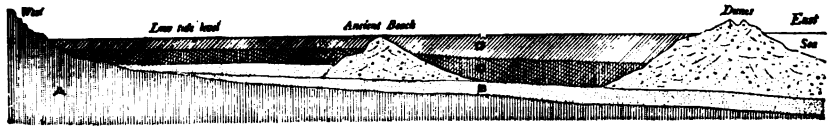
PLUM ISLAND MARSHES.

The Plum Island system of marshes near Newburyport, Mass., is perhaps the largest of any of the swamps of this description which exist north of Long Island Sound. If we take into account the connected areas of marine swamp lying to the north and south of those on Essex, Ipswich, and Hampton Rivers, the total area is more considerable than any other of the northern salt marshes, amounting in all, as will be seen from the appended catalogue, to over 20,000 acres.

It is worth while to give some special attention to this Plum Island district, for the reason that it shows more perfectly than any other area in New England the general way in which these structures are formed.

Any general map of New England will show that this district lies at the innermost part of the Bay of Maine, a deep re-entrant of the coast between Cape Ann and the mouth of the Bay of Fundy. The shores of this great bay were at the close of the glacial period deeply covered with detrital matter, which has been in good part swept into the sea. In part this work of removing the glacial waste to the sea was accomplished during the gradual retreat of the sea immediately after the close of the glacial period; in part it has been brought about by the action of the waves and tides upon the shore since the close of that time. In this region there has also been an extensive cutting away of the drumlins, till, and terrace drift since the sea acquired its present level. The sea to the eastward of this shore abounds in shallows which were probably land areas above the level of the water for a time after the close of the last glacial period, but have since that time been worn away by the waves. From these various sources the sea acquired possession of a large quantity of sand, which has served to shallow its bottom to the point where the waves, in periods of violent storms, could urge this sand towards the shore; the waves acting on the shore and the currents which they induce have served to convey a large amount of this sandy and pebbly matter to the bottom or most re-entrant part of the gulf.

The first result of this action was the shallowing of the water for a mile or two from the shore to a depth which made it possible for the waves to break in periods of great storms. This created a barrier beach along this part of the shore from Little Boars Head to Annisquam River, a distance of about 22 miles. As will be seen from the Coast Survey chart, this portion of the shore forms a gently re-entrant curve; only at one or two points, as at Great Boars Head, does the mainland break upon the continuity of the barrier beach. The only considerable interruptions to the continuity of this beach were formed by the action of the tidal and land waters, which, during the growth of the barrier, kept open several exits. These are at the mouth of Essex River, Ipswich River, and Merrimac River. At present there are only four of these inlets through the beach. There may have been more of these inlets before the scouring action of the tide was diminished by the lessening of the inclosed water basins through the formation of the peat marshes. As this space for the tidal waters diminishes, the outgoing mass of water becomes less and less able to maintain an open way against the sand, which is constantly heaped across its path by the action of the waves. One such exit has recently been closed—that at Hampton Beach—and that at Hampton Harbor is in danger of closure. When this closure of an exit occurs, the imprisoned waters are driven to find a way through the neighboring openings to the sea.



A. Bed rock. B. Sand and gravel. C. Eel grass layer. D. Upper marsh.

FIG. 55.—Diagrammatic section through Plum Island.

When this barrier beach was first created it seems to have been imperfect and much nearer the shore than at present. There are slight traces of such an ancient beach visible at various points in the marsh ground. When the outer beach was formed these original barriers seem to have been reduced to the level of the marsh by the action of the wind; they are now brought down to about the sea level, and are only indicated on the marsh by a slight ridge in the swamp area or the worn-down remains of the dunes dug out to their bases by the winds.

The formation of the marshes seems to have begun immediately after the formation of this outer or existing beach. The time when this ridge began to form cannot have been very remote; for, although it is widening with great speed, it has not yet attained to a width of more than a thousand yards, except in the extreme southern part, where it is a few hundred yards broader.

As the dune mass grows by accumulations made on its seaward face it loses on the landward side, the sand being blown over the surface

of the salt marshes. At certain points this blown sand forms a considerable element in the marshy matter.

It is probably to this cause that we owe the shallowness of the streams within the area of the marsh, which are notably less deep and have more sandy bottoms than those at other points along the shore. These sand invasions are particularly conspicuous on the northern end of the Plum Island marshes, near the line of the turnpike which connects the island with the mainland. Here the marsh is not over 2 feet in depth, and a considerable portion of this shallow deposit is composed of sandy matter.

The Plum Island marshes are very well placed for utilization: not only is the area very large, including many thousand acres, but the channels which traverse the area are, on account of their shallowness, but little used for boat harbors or any other purpose. The fresh water which pours through them is small in amount. The dam required to shut off the sea would not be costly when the area reclaimed is considered. The length of the dam required at the southern end will not exceed 3,000 yards; the dam at the northern end is already made by the embankment of the Plum Island turnpike and only requires flood-gates to control the water in channels about 200 feet in width. The greatest depth of water at high tide on the line of this dike will not exceed about 20 feet, and this for only a small part of its length. The average required height of the dam will probably not exceed 10 feet; an abundance of clay for the structure could be found immediately at the western end of the proposed dike. Its construction will be by no means a difficult engineering problem. The water storage spaces within the area are so large and the places for exit sluices are so extensive that it will be possible to lower the level of the water at least 5 feet below the surface of the marsh.

There is perhaps no point on the shore north of New York where so large an area could be secured from the sea at so slight an expense and with so small an effect on the harbor interests of the coast. The flow from these marshes through the exit of Plum Island River is small in quantity and in the main occurs in the first hour or two of the ebb. It is only at the Ipswich channel that any damage to important harbors could occur. There would undoubtedly be certain changes in the altitude of the sand-bars at this point in case these Plum Island marshes were barred from the tide, but how far these changes would affect the depth of water at the entrance to Ipswich River it is not easy to determine. It seems evident, however, that the injury to this port would be more than counterbalanced by the addition of this great area to the agricultural value of the district in which it lies. The present agricultural value of these marsh lands does not exceed about $10 an acre, or a total of say $150,000; if they should become worth $200 an acre they would represent a value of $3,000,000 and would maintain an agricultural population of about five thousand souls.

It should be noticed that the Coast Survey map includes only about three-quarters of the total marine marsh area which would be recovered by the proposed improvement.

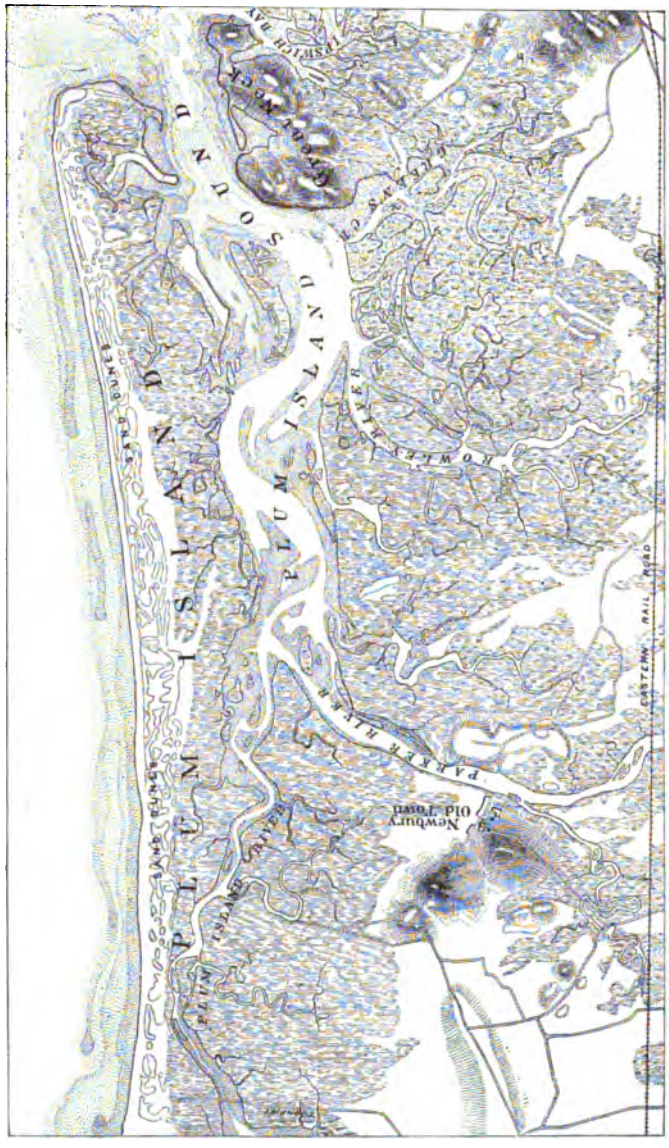


FIG. 56.—Plum Island marshes.

GREEN HARBOR RIVER DIKED LANDS.

The diked lands of Green Harbor River (or Cut River, as it is sometimes misnamed), in the town of Marshfield, Mass., constitute the most extensive experiment in the improvement of marine marshes which has been undertaken in New England. Although, as will be seen below, this

experiment has been carried on under somewhat exceptional conditions, the results are of great value from the light which they throw on the general economic problems involved in such enterprises. The Green Harbor River marshes cover an area of about 1,250 acres. They are separated from the sea by a barrier beach, formed by the action of the waves in the manner indicated in the first section of this report. From an early day, perhaps from the time of first settlement of this district by Europeans, in the seventeenth century, this beach was so continuous that the water found a difficult entrance to the marshes through channels leading in from Duxbury Bay. Thus, although these marshes had originally been in free communication with the sea, they had for many years been so far shut off from the incursions of the salt-water that at points farthest from the ocean the swamp had become brackish and many land plants could find root on its surface; moreover, the friction of the incoming sea-water in its tortuous channels was so great that the highest tides did not completely cover the area of the marshes.

FIG. 57.—Green Harbor River diked marshes. From Coast Survey charts Nos. 109 and 110. Scale, $\frac{1}{20000}$.

In 1810 a channel was cut through the sea wall at the point where is now the entrance of Green Harbor River. This entrance was quickly widened by the action of the tide, so that the sea speedily recovered all of the ground from which it has been partly excluded for some years. It is likely that this cutting merely reopened an inlet which had been closed by the action of the sea; it must have been a very low barrier, for, according to tradition, it was cut through in a night by a party of

fishermen. The low nature of the sea wall clearly indicates that there was originally an inlet at this point.

The result of this opening of the swamps to the readier incursion of the tide was at once to narrow the limits of pasturage lands along the shore of the marshes, to the detriment of the farmers' interests. After many years of debate, it was determined to apply to the legislature for authority to close the reopened inlet. This was granted, and in 1872 the dike was constructed at the expense of the adjacent landholders, a tax for its construction being laid upon all those whose lands were to be benefited by the improvement. At the time the project was essayed the lands were, to a great extent, held by persons who were unable or unwilling to meet the cost. The swamp lands were then valued at an average of not more than $5 an acre, those best situated selling for about $15 an acre. Such was the doubt concerning the issue of the undertaking that a large part of the owners sold their holdings to persons who bought them on speculation. The dam was built at a greater cost than the needs required, the total expenditure for it amounting to about $30,000. It proved entirely successful in keeping out the sea, but the sluice-gates were not large enough to lower the level of the waters in the marsh to more than 4 feet below its surface, while 6 feet of lowering was desirable. No system of side ditches was undertaken, although they were imperatively required for the proper draining of the great area of the swamp.

The effect of this exclusion of the sea was immediately perceptible. In one year after the completion of the dike a small portion of the land was sowed in English grass, without any plowing of the ground whatever; the second summer from the time of sowing—i. e, three years from the time when the salt water was excluded—this land gave excellent crops of hay.

Immediately upon the exclusion of the sea, the small anchorage at Green Harbor village, which had served the needs of a few fishermen and gunners for water fowl, began to silt up owing to the fact that the outgoing tide from the interior marshes no longer scoured out the channel. Although the economic importance of this change in the little harbor was slight, it led to a conflict in the courts, which was decided in favor of the owners of the dike. Some of the fishermen then endeavored to remove the dike by force; twice the timber part of the dike at the sluice-way was blown up with dynamite, once in an effective manner. A third effort was frustrated, and a man is now under bonds for trial for the offense.

The result of these regrettable conflicts has been to retard the work of culture of these lands, which have been fairly won from the sea and are secure from all natural dangers. Only about 100 acres of this area have actually been brought into tillage, and this in a very imperfect manner; the farmers, all men of small capital, are naturally unwilling to venture expense in subjugating and planting lands which may be

flooded whenever a miscreant succeeds in breaking down the barrier which protects them from the sea. The speculators, who control a large part of the lands, are holding them for the price which they may expect to obtain when the dam becomes well secured against molestation. At present this barrier has to be guarded day and night by watchmen.

The work of tillage has already shown that the expectations of gain from the improvement were well founded. Although none of the land has been properly ditched and the plowing has been of a very poor sort, excellent returns have been won from the soil.

The crop requiring the least tillage is hay; this is said to yield as much as two tons an acre at the principal cutting, even in areas where the soil has received no plowing or other care. It is said that on well-prepared land much larger yields have been obtained. With a slight plowing, the following crops have been planted and have yielded returns as follows: Oats, 45 bushels to the acre; rye, 40 bushels per acre; wheat, said to yield well, but amount not determined; maize, a variable crop on account of its intolerance of salt, but 75 bushels to the acre have been harvested; of onions, large crops are obtained, but the quantity to the acre has not been determined; potatoes yield large crops.

I cannot ascertain that any crop has as yet failed to show a fair promise in this soil.

The criticisms that are made on the soil are that it is rather wet and that the light top mold is apt to wash away, leaving the tough roots of the dead salt-marsh grass exposed. This latter difficulty seems only to be met where the soil has been planted in grass without any tillage, and is doubtless avoidable by a proper system of plowing. The former difficulty is clearly due to the absence of proper ditching, as is shown by the fact that the land within 100 feet of a ditch is generally dry enough for all needs, despite the fact that the water level is never more than about four feet below the surface of the land and is often within three feet of its level.

The principal point in the economic problem has thus been satisfactorily determined by the experience in these improvements; the land has proved fertile and tillable. The ordinary crops of the country do well upon it, and their growth promises to prove more and more satisfactory as the ground is longer tilled. The elements of difficulty which have been encountered are in good part unessential, though they have a very distinct bearing on the management of such enterprises in the future. There has throughout been a great lack of business skill in the management of this property. If the work had been in the hands of a strong company, success would have been attained sooner than it has been. The dam probably could have been built at less expense, and the water could by proper sluices have been kept at a lower level. The lands would have been sufficiently ditched, and it would probably have been found advantageous to plow them once by steam-power, thus break-

ing up the mat of grass roots which make plowing by the ordinary means a difficult process. Above all, such a company would have given a measure of security against willful injuries to the dam, which it is not easy to effect under the present management. Again, the company might have found it well to bring upon the ground agriculturists from the Netherlands, or other countries, who are familiar with the use of such lands, thus winning some of the experience in a work which is unfamiliar to New England farmers, but is well known to those of Northern Europe.

Some of the promoters and owners in this improvement estimate the original value of these lands at $5 an acre and the present value at $250 an acre. The latter estimate, though apparently high, seems fairly to be based on the crop returns. To secure on the best upland soils of the neighborhood yields similar to those won from the unmanured marshes requires, it is said, the expenditure of at least $25 per annum in manures. If this be the case, and if, as seems likely, the marshes can be cropped for twenty years or more without fertilizing and with no greater expenditure of labor than is required in the uplands, their lands, when properly prepared for tillage, should have at least the value above assigned to them.

If the preparation of this area of marshes had been carefully conducted, the dike would probably have cost not over $15,000; the ditches properly required for the beginning of systematic tillage, about $30,000, or a cost of about $40 per acre, to which, if we add the original value of the land, we shall still have a cost of less than one-fifth its estimated value.

An examination of the area of marshes shows some interesting features, which have a distinct bearing on the problem of winning similar grounds to tillage. It is evident that a certain amount of subsidence has occurred from the decay in the vegetable matter in the mass. It is not easy to determine the average amount of this change in level, but it probably amounts to somewhere near 8 inches over the whole surface. It is likely that it will increase to about double that amount.

On examining the untilled part of the swamp, it is clear that the salt tends to work to the surface, especially during a period of drought. There is a distinct coating of saline matter, partly decomposed, disposed in the form of patches over the areas at a distance of a few hundred feet from the natural drains. This is not observable on the tilled portion of the marsh. It is due to the upward working of the imprisoned salt water, which rises to replace the water which is evaporated at the surface. This upward working of the saline matter will doubtless be interrupted by the process of tillage. In a few years the limited supply of salt will be exhausted, especially if the area shall be guarded from any abnormal invasion of salt water, such as was brought about by the recent blowing up of the sluice-ways.

PRINCIPAL AREAS OF SALT MARSHES BETWEEN THE HUDSON RIVER AND PORTLAND, ME.

The following list has been prepared with the view of giving the more important facts concerning the distribution of the areas of salt marshes between New York and Eastern Maine. Unless otherwise stated the estimates of areas are taken by approximate measurements from the United States Coast Survey printed charts. They are in most cases correct within a limit of error of less than one-twentieth of the estimates. The area of the mud-flats, which in the majority of cases are largely the product of the action of the waves in the upper or true marsh level, is not generally given. In the region south and west of Boston this mud-flat area lies within the limits of reclamation, and will perhaps add one-fifth to the area of winnable land in that part of the coast. North of Boston the increased height of the tide makes it a matter of serious expense to defend the lower-lying mud-flats from the sea; still, nearly the whole of their surface in the region south of Portland is far within the limits of the conditions under which such lands have been won in Holland. It is much to be desired that a careful survey of these and the other swamp deposits of the Atlantic coast belt be made. This should include a comparison between the American coast marshes and those of North Europe. It will be well to have these studies include also the similar formations on the Pacific shore.

Besides the areas given in the following lists, which are taken from the Coast Survey charts, there is a considerable quantity of salt marsh land lying farther inland than these maps extend. There are as yet no satisfactory topographic data for estimating this unmeasured area, but from the best accessible sources of correction it seems likely that these unmeasured portions of the sea marshes amount to not less than one-twentieth of the area given below. The measurements as given were made from the printed sheets of the Coast Survey charts by means of a planimeter of French manufacture, maker unknown. The instrument has been repeatedly tested by comparing its measurements with those where other forms of measurement have been obtained. The results have appeared to be more trustworthy than those attainable by any other mode of determining the areas which could be applied.[1]

The position of the areas is indicated by the latitude and longitude; they are likewise designated by the name of the nearest named river or inlet as given on the map. Owing to the obscurity of the divisions between many of these marsh areas it has been found necessary to assume divisional lines; these appear on the original record maps, but they are stated in an arbitrary way in this catalogue. It will be ob-

[1] A careful testing of the planimeter on twenty selected areas has established the probable combined error of instrument and observer approximately as follows: For an area of 40,000 acres, 260 acres; for an area of 1,000 acres, 30 acres.

served that the list stops near Portland, Me., few of the marshes to the east of that line appearing in the catalogue.

The total area of these marshes within the State of Maine is not large and a considerable portion of the coast, viz, from Mount Desert to Calais, is not yet mapped. It therefore seemed unnecessary for the purpose of this memoir to extend the measurements east of Casco Bay. The marsh areas on Martha's Vineyard and Nantucket islands were not measured. On the maps of these districts the marshes are imperfectly designated. They are, in fact, curiously blended with the sand flats, and, owing to the frequent closure of the lagoons in which they are formed, it is hard, in many cases, to determine whether they belong to the salt or to the fresh water group of marshes. Detailed geological reports on these islands are now in preparation; in them the condition of these marshes and their fitness for improvement will be carefully considered. I am indebted to my assistant, Mr. Alfred Church Lane, for the measurements and computations given in the following catalogue.

Catalogue of the larger salt marshes of New England and Long Island, N. Y.

[The word "incomplete" indicates that the marsh extends farther in than the area mapped on the Coast Survey sheet. Where the number of acres is bracketed [ ] it indicates the area including the surface of inclosed water. An interrogation mark ? shows that the accuracy of the measurement is doubtful.]

Number and name of chart.	Latitude.	Longitude.	Locality.	Area in acres.
	° ′	° ′		
107. Seguin Island to Kennebunkport, Me.	43 18	70 34	Wells Village; one-tenth water ...	1,265
	43 21	70 32	Little River	176
	43 21	70 30	Coast to Kennebunkport.....	336
	43 21	70 26	Vaughn's Island and neighborhood.	48
	43 22	70 25	Sampson's Cove	16
	43 23	70 25	Goosefair Creek, both branches...	304
	43 25	70 23	Little River	272
	43 27	70 21	Back of Fletcher's Neck.....	128
	43 28	70 24	Saco River	144
	43 30	70 23	South end of Old Orchard Beach .	208
	43 33	70 20	Scarboro Beach and Prout's Neck; incomplete.	1,265
	43 35	70 15	Spurwink River	480?
	43 48	70 09	Yarmouth River	32
	43 49	70 09	Cousin's River.....	64
	43 44	69 49	Morse River and Atkin's Bay	569
	43 46	69 46	East side of mouth of Kennebec..	32
108. From Wells to Cape Ann.	42 37	70 41	Squam River; one-half water	[1,376] 688
	42 38	70 45	Essex River; one-half water; incomplete.	2,846

Catalogue of the larger salt marshes of New England, &c.—Continued.

Number and name of chart.	Latitude.	Longitude.	Locality.	Area in acres.
	° ′	° ′		
108. From Wells to Cape Ann—continued.	42 41	70 48	Ipswich River to margin of Green's Creek, bounded by road; incomplete.	2,942
	42 45	70 48	Plum Island marshes (Green's Creek and Rowley and Parker Rivers); incomplete.	9,280
	42 50	70 50	East Salisbury, Black Rock, and Town Creeks to R.R.; incomplete	1,692
	42 53	70 49	Hampton Harbor; incomplete ...	5,076
	42 58	70 46	North Hampton	47
	42 59	70 46	North of Rye Ledge.....	32
	43 00	70 45	Rye Harbor	269
	43 01	70 41	Panson's Creek	285
	43 02	70 43	Little Harbor	237
	43 05	70 40	Marsh south of Cutts Island.....	63
	43 06	70 39	Marsh north of Cutts Island.....	332
	43 08	70 39	York River.....	32
	42 59	70 37	Isles of Shoals; estimated.....	32
	43 10	70 37	South of Cape Neddick; estimated.	47
	43 12	70 35	Near Pond Rocks; estimated.....	32
	43 16	70 35	Wells Beach; incomplete	253
109. Boston Bay and approaches.	42 19	71 03	Old Harbor, South Boston	332
	42 20	71 04	South Bay; all filled	400
	42 21	71 05	Back Bay; two-thirds water (as it was); incomplete.	2,277
	42 24	71 05	Mystic River to Lynn Pike; one-third water.	[2,515] 1,677
	42 23	71 01	East Boston	176
	42 23	71 00	Chelsea River	1,202
	42 26	70 59	Saugus River, &c.....	1,487
	42 25	70 55	Nahant	144
	42 26	70 53	Phillips Beach.....	112
	42 30	70 53	Back of Marblehead; one-half water.	[316] 158
	42 33	70 54	Danvers; incomplete	140?
	42 34	70 49	Beverly farms	80
	42 35	70 44	Manchester	80
	42 37	70 38	North of Eastern Point.....	112
	42 04	70 40	Back and Cut Rivers.....	1,107
	42 05	70 40	Bass and Green Harbor Rivers....	1,234
	42 07	70 41	South River; incomplete	633

Catalogue of the larger salt marshes of New England, &c.—Continued.

Number and name of chart.	Latitude.	Longitude.	Locality.	Area in acres.
	° ′	° ′		
109. Boston Bay and approaches—continued.	42 09	70 43	North River; incomplete; one-third water.	[2,293] 1,529
	42 11	70 43	Scituate Harbor; one-tenth water	[208] 187
	42 15	70 46	Cohasset Harbor; one-tenth water.	[759] 683
	42 16	70 50	Near Jerusalem Road	112
	42 16	70 51	Near Jerusalem Road; two-thirds water.	[256] 85
	42 17	70 52	White Head Flats	144
	42 15	70 54	Hingham Harbor, Otis Hill; one-eighth water.	[160] 140
	42 14	70 55	Weymouth Back River; one-half water.	[648] 324
	42 14	70 57	Weymouth Fore River; four-fifths water.	[585] 117
	42 15	70 58	Town River and Hough's Neck; one-half water.	[618] 309
	42 16	71 00	Black's Creek and neighborhood; one-tenth water.	[192] 173
	42 17	71 02	Neponset River and Squantum; one-fifth water.	[1,661] 1,329
110. Cape Cod Bay.	42 03	70 38	Duxbury Beach	474
	42 03	70 38	Back River Islands	95
	42 03	70 38	Duxbury shore	190
	42 00	70 42	Jones' River and shore, east to Standish Monument.	316
	41 57	70 41	Between Jones' River and Plymouth.	174
	41 57	70 38	South end of Long Beach	47
	41 51	70 32	Centre Hill Point and southward	95
	41 47	70 30	Bass, Scusset Mill, and Dike Meadow Creeks.	1,044
	41 46	70 28	Old Harbor, Meuset, Spring Hill, Dock and Mill Creeks.	822
	41 45	70 26	Cows', Long, and Scorton Harbor Creeks.	459
	41 43	70 22	Scorton Creek and Great Marshes; one-fourth water.	[4,110] 3,982
	41 43	70 14	Rendezvous and Lone Tree and Chase Gardner Creeks.	1,787

Catalogue of the larger salt marshes of New England, &c.—Continued.

Number and name of chart.	Latitude.	Longitude.	Locality.	Area in acres.
	° ′	° ′		
110. Cape Cod ay —continued.	41 45	70 09	Sursuit Creek	158
	41 45	70 07	Quivett Creek, &c., to Brewster	348
	41 48	70 00	Brewster to Herring River, coast marshes.	933
	41 54	70 00	Blackfish Creek and Horse Island.	949
	41 57	70 03	Herring River, Wellfleet	3,416
	42 00	70 03	Pamet River, &c	474
	42 03	70 06	Peaked Hill Bar. The swamp is back of it.	380
	42 03	70 12	Little swamps around Provincetown.	142
	41 49	69 57	Marshes near Town Cove; one-third water.	[174] 116
	41 46	69 56	Near Pochet Island	569
111. Monomoy and Nantucket Shoals to Muskeget Channel	41 46	69 56	Near Life-Saving Station No. 12	190
	41 40	69 57	Near Morris Island	111
	41 40	70 05	Harwich Marshes	158
	41 40	70 09	West Dennis	142
	41 40	70 08	Swan Pond River	269
	41 38	70 13	Pond east of Lewis Bay	190
	41 36	69 58	Wreck Cove, Monomoy	190
112. Muskeget Channel to Buzzards Bay.	41 38	70 19	Back of Hyannis Point	554
	41 38	70 21	West of Centreville Village	142
	41 37	70 25	Osterville Harbor	469
	41 36	70 27	Poponesset Bay	158
	41 34	70 30	Waquoit Bay, east side	16
	41 34	70 33	Waquoit Bay, west side	110
	41 34	70 35	Ponds south of Falmouth	127
	41 25 to 41 32	70 40 to 70 55	Elizabeth Isles; a number of marshes, salt or fresh?	127
	41 34	70 39	West of Falmouth	47
	41 34	70 38	North of Hamlin Point	95
	41 38	70 38	Wild Harbor and Herring Pond Creek.	127
	41 42	70 38	Pocasset Harbor and North Pocasset.	190
	41 44	70 37	Monumet River and south	316
	41 45	70 39	North of Wicket's Island	32
	41 46	70 41	Agawam; one-half water	[95] 48
	41 45	70 43	Johnson's Creek	111

Catalogue of the larger salt marshes of New England, &c.—Continued.

Number and name of chart.	Latitude.	Longitude.	Locality.	Area in acres.
	° ′	° ′		
113. Cuttyhunk to Block Island.	41 32	70 57	Mishaum Point; incomplete	63
	41 32	70 58	Barney's Joy Point; incomplete	32
	41 31	71 00	Allen's Pond	480?
	41 31	71 03	Westport and various islands near by.	1,756?
	41 31	71 05	Acoakset River; incomplete	696?
	41 30	71 07	No name	111
	41 29	71 10	No name	253
	41 33	71 12	Nonquit Pond	127
	41 35	71 12	Back of Sapowet Point	300
	41 29	71 15	Sachuest Beach, Newport	111
	41 29	71 17	Easton's Pond, Newport	111
	11 27	71 19	The Neck, Newport	47
	41 43	71 11	Near Lee's River	47
	41 40	71 17	Popasquash	63
	41 43	71 17	Warren River	47
	41 44	71 20	Nayat Point	79
	41 39	71 20	Prudence Island, northern part	127
	41 38	71 19	Prudence Island, middle part	158
	41 37	71 25	Mainland west of Prudence Island; estimated.	63
	41 27	71 27	Back of Little Neck; ½ water	332
	41 23	71 30	South of Point Judith Pond	490
114. Long Island Sound, eastern part.	41 04	71 55	Great Pond; end of Long Island	285
	41 00	72 03	Napeague Harbor	332
	41 01	72 08	Acabomock	316
	41 20	72 02	Poquonock River	269
	41 19	72 01	Mumford's Cove	79
	41 21	71 57	Mystic River	364
	41 20	71 55	Wamphassuck Point	127
	41 21	71 54	Quanaduck Cove	63
	41 21	71 52	About Wicketequock River	427
	41 19	71 47	Babcock's Pond	332
	41 20	71 43	Quonocontaug Pond	174
	41 22	71 38	Ninigret and Green Hill Ponds	538
	41 23	71 30	Point Judith Pond	474
115. Long Island Sound, middle part.	41 08	72 15	Oyster Pond	886
	41 06	72 22	About Stirling and Greenport	127
	41 05	72 21	Derring's Harbor	16
	41 03	72 20	West Neck Harbor	32
	41 04	72 19	Coecle's Harbor	32
	41 01	72 12	Three-Mile Harbor	127

Catalogue of the larger salt marshes of New England, &c.—Continued.

Number and name of chart.	Latitude.	Longitude.	Locality.	Area in acres.
	° ′	° ′		
115. Long Island Sound, middle part—cont'd.	41 02	72 13	Ely's Brook	79
	41 00	72 22	Jessup's Neck	32
	40 56	72 26	Jessup's Neck, large swamp	569
	41 00	72 27	Cutchogue Harbor	253
	41 02	72 25	Great Hog Neck, east side; two-thirds water.	300
	41 02	72 25	Great Hog Neck, west side	32
	41 03	72 28	Goldsmith's Inlet	16
	41 00	72 35	Mattituck Pond	47
	40 59	72 37	Luce Landing	16
	40 55	72 37	Flanders, Riverhead, Aquebogue.	2,182
	40 57	72 51	Wading River	142
	41 13	73 02	Indian River	364
	41 14	72 59	Oyster River	127
	41 15	72 57	Savin River	127
	41 16	72 57	West Haven	47
	41 17	72 56	New Haven	316
	41 17	72 54	West side of New Haven Bay	221
	41 15	72 53	Morris Creek and Farm River	775
	41 15	72 51	East of Saltonstall's Lake; incomplete.	47
	41 16	72 48	Branford Harbor and River; incomplete.	728
	41 15	72 50	Branford Point	32
	41 16	72 45	Around Stony Point	221
	41 16	72 44	East of Stony Point	206
	41 16	72 42	North of Sachem Head	300
	41 15	72 41	East of Sachem Head	127
	41 16	72 39	Guilford Harbor and East River	1,392
	41 16	72 36	South of Madison	111
	41 16	72 32	Hammonasset and Indian Rivers; incomplete.	981
	41 16	72 30	East of Killingworth Harbor	427
	41 17	72 28	Westbrook, Menunketesuck	469
	41 17	72 26	Near Salt Island	79
	41 17	72 24	Oyster River, Saybrook	633
	41 17	72 22	North and South Coves and a little creek above.	648
	41 18	72 20	Lieutenant's, Back, and Blackhall Rivers.	838
	41 21	72 22	Calves', Goose, and Nott's Islands and Ely's Ferry; incomplete.	390

Catalogue of the larger salt marshes of New England, &c.—Continued.

Number and name of chart.	Latitude.	Longitude.	Locality.	Area in acres.
	° ′	° ′		
115. Long Island Sound, middle part—cont'd.	41 21	72 22	Essex; incomplete	158
	41 17	72 17	East of Griswold's Point	158
	41 18	72 15	Near Hatchett's Point	126
	41 18	72 14	Four-Mile River and next creek east.	95
	41 18	72 13	Bluff Island and adjacent	127
116. Long Island Sound, western part.	41 12	*00 56	Back of Charles Island	300
	41 11	*00 53	Stratford, Islands, &c	100†
	41 12	*00 54	Housatonic River; incomplete	158
	41 10	*00 52	South of Stratford	1,582
	41 09	*00 48	South of Bridgeport	300
	41 08	*00 45	Pine and Fairfield Creeks	633
	41 08	*00 44	Southport, Mill River	237
	41 07	*00 41	Green Farms; one-fourth water	[443] 332
	41 06	*00 39	Saugatuck River, east bank	63
	41 06	*00 38	Saugatuck River, west bank	332
	41 05	*00 36	Norwalk River	664
	41 03	*00 33	Five-Mile River to Long Neck Point.	380
	41 03	*00 31	Darien River	111
	41 02	*00 29	Stamford Harbor and east	712
	40 58	*00 59	Mount Sinai Harbor	285
	40 55	*00 50	Stony Brook Harbor and East Flats.	474
	40 53	*00 48	Nissequague River; two-thirds water.	[633] 211
	40 54	*00 45	West of Nissequague River	206
	40 56	*00 41	Crab Meadow	316
	40 56	*00 37	Northport Bay	111
	40 53	*00 35	Huntington Harbor	32
	40 56	*00 31	Meadows, Lloyd's Point	32
	40 52	*00 30	Oyster Bay Harbor	79
	40 54	*00 26	Mill Neck Creek	300
	40 54	*00 24	Fox Island to Lattingtown	221
	40 54	*00 22	Dosoris Pond	79
	40 52	*00 22	Mosquito Cove	150†
	40 52	*00 18	Prospect Point	63
	40 48	*00 21	Roslyn	32
	40 48	*00 18	Head of Manhasset Bay	127
	40 46	*00 15	Little Neck Bay	237

* Longitude east of New York City Hall.

Catalogue of the larger salt marshes of New England, &c.—Continued.

Number and name of chart.	Latitude.	Longitude.	Location.	Area in acres.
	° ′	°		
116. Long Island Sound, western part—cont'd.	40 49	*00 12	Throg's Neck	127
	40 52	*00 12	Hutchinson's River; incomplete	601
	40 53	*00 12	Along the coast, Rodman to Davenport's neck.	474
	40 54	*00 14	New Rochelle	95
	40 55	*00 15	Delancey Cove	316
	40 56	*00 17	Mamaroneck	221
	40 57	*00 19	Mill Creek	316
	40 58	*00 20	Manursing Island	190
	41 00	*00 21	Port Chester	47
	41 01	00 23	Bush's Harbor	127
	41 02	*00 25	Coscob Harbor	158
	41 01	*00 26	Greenwich Cove	348
118. Southern coast of Long Island, middle part.	41 01	*1 49	Three-Mile Harbor	63
	41 00	*1 45	North West Creek	316
	41 00	*1 42	Sag Harbor	63
	41 00	*1 39	Noyack	95
	40 56	*1 35	Cow Neck and North Sea Harbor	490
	40 54	*1 30	Canoe place	79
	40 54	*1 26	South Port	300
	40 52	*1 28	Tiana	111
	40 50	*1 25	Shinnecock Bay, shores of	696
	40 50	*1 25	Quogue	?
	40 47	*1 17	Around Moriches Bay:	
			Petunk	491
			Between Petunk and Forge River	554
			Front Beach, &c	949
119. Southern coast of Long Island, western part.	40 37	*00 25	Hempstead Bay	4,064
	40 36	*00 28	South Oyster Bay Islands	1,787
	40 39	*00 30	Shore (long. 0° 27′ to 0° 35′) and Great Island.	3,116
	40 37	*00 31	Islands	996
	40 37	*00 34	Jones Beach and adjacent islands	1,755
	40 41	*00 40	Coast inside (long. 0° 35′ to 0° 45′)	1,866
	40 38	*00 40	Oak Island beach and adjacent islands.	2,704
	40 43	*00 45	Long. 0° 45′ to Connetquot Brook	1,487
	40 39	*00 49	Fire Island	253
	40 43	*00 53	Connetquot Brook to Edward's Landing.	712

* Longitude east of New York City Hall.

Catalogue of the larger salt marshes of New England, &c.—Continued.

Number and name of chart.	Latitude.	Longitude.	Locality.	Area in acres.
	° ′	° ′		
119. Southern coast of Long Island, western part—continued.	40 44	*00 56	Brown's Point	206
	40 44	*00 59	Blue Point and Mill's Landing	158
	40 45	*00 59	Patchogue Landing	79
	40 45	*1 02	Swan Creek to Howell's Point	474
	40 46	*1 06	Bellport Bay	886
	40 45	*1 09	Smith's Point to end of chart	712
120. New York Bay and Harbor.	40 45	73 50	Flushing Bay	1,978
	40 49	73 50	Westchester Creek	538
	40 49	73 51	Just west of Westchester Creek	316
	40 49	73 52	Broncks River	380
	40 48	73 55	Mott Haven and Port Morris	601
	40 46	73 54	Near Berrians Island	253
	40 44	73 57	Hunter's Point	1,218
	40 36	73 47	Rockaway Beach	459
	40 37	73 50	Islands in Jamaica Bay	3,732
	40 37	73 50	Coast around Jamaica Bay	11,070
	40 35	74 00	Coney Island	949

*Longitude east of New York City Hall.

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